SELECTION, TRAINING and SIMULATION

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1. GENERAL BACKGROUND

1.1. THE SUPERAGILITY ARENA

Superagile aircraft systems are a new challenging era in aviation history. These aircraft systems will be able to operate within new limits. Some of the areas of the super agile concept have already been explored in flight. Vectored thrust flying has been practised in aircraft such as the X-31, SU 37 and F-18 HARV.

New aircraft sensors, sensor-fusion and data-link techniques have made the battlefield much larger than before. The introduction of the night vision aids has also opened a whole new area.

Agile weapon systems make the scenario even more intriguing.

1.2.THE HUMAN CHALLENGE

How much of a limiting factor will the human become in super agile flight? Will he still have a place in this arena. And if he will operate on board super agile systems will he be able to do so without compromising his health?

We know since the introduction of first flight, that aviation does have an effect on aviators. Ever since Paul Bert studied the effects of high altitude, scientists and flight surgeons have been involved in studying the interactions between aviation, aviators and the aviation environment. The introduction of super agile aircraft systems will therefore most likely be an exciting chapter in the book of aviation medicine.

Flying these new generation fighter aircraft will be a new experience in a new threat environment. Improved engines will make it possible to fly at high altitude. To avoid adverse weapons from beyond visual range high linear and angular velocities and accelerations will be needed. In close combat situations vectored thrust gives high manoeuvrability at low speed and the super agile pilot will thereby have better possibilities to win and survive.

The flight environment will also hold new threats and players as super agile adversary aircraft with super agile weapons, unmanned aerial vehicles (UAV's) and powerful data links. This will certainly make the battlefield even larger. Although artificial intelligence and remote team members will help to diminish workload, the pilot on board will be a crucial part of the superagility complex.

In this highly complex flight environment the pilot will be submitted to different hazards. He has to be able to perform well under the given conditions. He will have to accomplish his mission and survive to allow him to fly a next one. All this has also to be done without compromising flight safety or the long-term effects on the pilot's health.

In this chapter an attempt will be made to approach the issues of how to select the right stuff and then how to train them to be efficient players in the superagility arena.

1.3. HUMAN CHARACTERISTICS

1.3.1.Limitations

In flying man's limitations become quite visible. Man has his information limits. He works cognitively more in a serial way, i.e. not too many bits of information at a time (**1**). Compared to most machines man is structurally fragile. And man is easy to fatigue.

In the context of a very multipotent aircraft system it is quite visible that man implies a restriction for the superagile system in some aspects. Yet technological systems without direct human participation have so far proved to be inferior compared to systems where man has his given role.

1.3.2.Strength factors

Adaptability when situations change. This means adaptation of both the cognition and of physiology. Adaptation usually takes some time and involves training. *Development of knowledge*. Man is a self-educating system where training again is an important factor. The ability to *communicate*. With intuition and creativity man normally also will outperform technical systems in pattern-recognition.

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1.4. FLIGHT SAFETY AND HEALTH RISKS

In order to find the criteria for selection and retention of super agile pilots one also has to identify and assess the risks of the super agile arena as well as the positive qualities that these pilots will have to have. In an occupational medical approach if these risks cannot be eliminated they have to be isolated. The next step is to give personal protection to those individuals who can meet the criteria of doing the job without compromising health and safety. Briefly some of the main concerns can be mentioned.

High altitude and radiation will stress the issue of oxygenation of human tissues, protective clothing for both body and eyes and survivability in case of ejection.

Acceleration will mean sustained high Gz, other G-vectors, push-pull effects and all these acceleration stresses will be combined with a lot of vestibular peculiarities. And beside the accelerative effects on the cardio-vascular system the spine, assisting muscles and joints will be strained.

Night-vision aids and helmet-mounted displays will both create a focus on flight safety issues and physiological factors. The visual system will also be at danger due to new laser and microwave weapons.

One issue that not by itself is related to the superagile flight is noise. But since there still are a lot of problems in today's flying, this issue must be remembered also in coming superagile systems.

Last but not least the whole spectrum of pilot workload must be remembered. This area can be predicted to be the issue of greatest concern.

1.5. HUMAN AGILITY

Superagility with its different aspects and reciprocal relationships is dealt with in other chapters of this work. Human agility is a key-factor, which in this context can be seen as an ability to interact with Aircraft agility, Systems agility and Weapons agility. This can be done if a well-developed Pilot-Vehicle-Interface (PVI) gives the right prerequisites. Real Human agility can be reached if selection has been performed optimally and training designed after expected scenarios (Figure 5.1.5-1).

When man is accepted as part of the Superagility system this must lead to a revolutionary attitude in how to develop new aircraft systems. These new systems have to be built for and adapted to man. The old attitude to build an aircraft and try to adapt man and make him fit into a technological experiment, is obsolete.

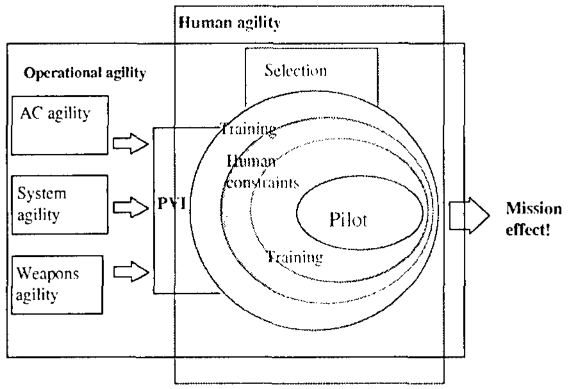

Figure 5.1.5-1 Human agility in the Superagility context

2. SELECTION

Selection should stand for the *best possible matching* between physiological and psychological resources versus the given operational requirements.

2.1. SELECTION- INTRODUCTION

With a classical definition selection refers to any process, whether natural or artificial by which certain organisms or characteristics are permitted or favoured to survive and reproduce in preference to others. It intents to pick out a number of individuals chosen from a group, by fitness or preference. In pilot selection the system tries to identify those individuals who will do best as a pilot in an operational setting.

The topic selection always starts a vivid discussion. Not only is it difficult to identify those individuals. It can also be debated if medical doctors or psychologists are best suited for such a task. In some countries experienced pilots take part in the selection by making interviews. This is a wise move since these experienced pilots are the criteria themselves.

Selection has in this time frame a negative connotation for many individuals and groups. The intention, some state, cannot be to exclude candidate pilots in order to create a whole new brand of super pilots. But, others reply, is a fighter pilot performing less than a top athlete?

On some of the arguments agreement is easily reached. We do need to identify those individuals that are able to fly, and accomplish their mission,

without compromising flight safety. Therefore no foreseeable medical conditions should exist that creates a chance of sudden incapacitation. Also agreement can be reached on simple issues. The candidate should have two eyes, two hands and he should be able to hear. But it becomes more difficult if a specific quantity or quality of cognitive intelligence, sensory function or muscle strength, aerobic capacity etc., is asked for.

Part of the reluctance may lay in the fact that it is difficult to identify all these traits and abilities. And prediction becomes more difficult because most air forces select future pilots out of young adolescents that are high school or college students or graduates. At that stage it is difficult to predict future physical and psychological status and performance. Not only the body is not full grown yet, but also personality and character will mature. Moreover in adolescence motivation can still change easily. Fortunately these young men and women can still be trained and shaped well. If well organised, this training is in our own hands.

But even if everybody willingly agrees that selection of pilots is a dedicated task, there seem not to be any profound revaluation of the selection issues.

Essentially all the criteria, which have been used for decades, still are in use. The prediction of success according to these criteria does not hold for more than completion of the basic flying training. Furthermore most interest seem to focus on the development of automated tests and how to get sufficient numbers of applicants for the flying training.

2.2. CURRENT SELECTION

In all air forces psychological techniques are used to predict if applicants have the right stuff to become a pilot. Usually the success rate of pilot training is used as a criterion. It would be better to predict the success as a future fighter pilot. Not all people that do well in training end up as the aces at the squadrons. This apparently is difficult to do.

Much at this age has to do with motivation. But some abilities can fairly well be predicted. In the different air forces different selection procedures are used that for a part are due to the different recruiting strategies.

Mostly a selection battery is based on a strategy to waste out those individuals with little changes early with low budget techniques. These tests are still more or less paper and pencil like. They are sensitive. The possibility is high that also usable candidates are rejected, but as long as the number of applicants is high enough, that is not a major concern.

Than sooner or later more specific and more expensive tests are introduced. Ranging from computer tests to simulators and actual flying. Some of the different test batteries are briefly discussed.

2.3. CURRENT METHODS

In Canada the "Canadian Automated Pilot Selection System (CAPSS)" is being used after the paper and pencil tests. It is a stand-alone selection device, which provides a measure of complex cognitive abilities and psychomotor co-ordination. The underlying constructs CAPSS is measuring are psychomotor co-ordination, learning rate, multi-task integration and performance under overload. It uses flight simulation technology and is comprised basically of two main elements, an aviation trainer and an analysis centre.

The United States Air Force uses a pre-screening before submitting candidate pilots to a selection board. They first have to pass the selection for officer commissioning. The selection decisions are based on leadership potential, educational achievement, physical fitness and ability based on paper and pencil or computer-based tests. There are no job sampling tests. Than there is a flight screening consisting of 23 hours of flight. The Air Force Academy policy is slightly different. They accept students not before they passed the flight screening. Since 1993 some experiments have been done with computer based aptitude tests. The selection research is focussed on learning ability. The goal is to develop a multiple test battery that predicts the different specific learning abilities. Analysis of the tests now used show that in predicting success in pilot training verbal abilities relate less than quantitative or spatial abilities.

The French Air Force

The Royal Netherlands Air Force

The German Air Force

The Swedish Air Force also uses pre-screening before applicants are subjected to the pilot selection. The conscript-time has to be finished with a rating as suitable for an officer's career. The tests are carried out over a two-day period, which on the first day include a general aptitude test to assess logical and spatial capacity and verbal ability. Those who progress through these stages proceed to the second day where they are given aptitude tests for co-ordination and simultaneous capacity. Applicants also undergo two interviews, one with a flight psychologist and one with a current line pilot. If successful so far the applicant will go on to two days of aeromedical tests. Thereafter the Selection Board will make a final decision.

The Royal Air Force uses the Pilot Aptitude Test Battery, consisting of five executives tests: Control Velocity Test (CVT, eye-hand co-ordination), Sensory Motor Apparatus (SMA, hand-food co-ordination), Instrument Comprehension (INSB, interpretation of instrument dials)), Vigilance (memory needing visual attention) and Digit Recall (short term memory). The test has a predictive validity of 0.52.

2.4. SUPERAGILE SELECTION

Introduction of super agile flight will not change the validity of old abilities and capacities. All principles that already are valid for current selection processes will also apply for that of super agile fighter pilots. One can also speculate that most of the selection criteria and variables of today might increase in importance. Yet there might be a need for something more or a different focus.

There are always scientific advances in the field of expertise and what are the extra demands of new technologies. For those reasons Nato's Aerospace Medical Panel (AMP), now Human Factors and Medicine Panel (HFM), held a conference in 1996 on Selection and Training Advances in Aviation (**2**). Some of the presentations already addressed the challenges of the super agile arena.

A thorough analysis has to be done of the qualifications and resources a pilot need for the superagility arena. Since these new requirements have not been confirmed and agreed upon this section will bring up some ideas of possible new selection-criteria or suggest stronger emphasis on some old criteria.

2.4.1. The visual system

The *visual system* plays a most important role in flying. This is very natural since the eyes are the best correcting means. In the agile arena this will be even more important. Some of the new tests will certainly involve the way the visual system works.

How to select those capable of much more *cognitive work* while at the same time being able to react properly on *orientation cues*?

How to select those with a *true spatial ability*, bearing in mind that most tests of today could not differ between a high intellectual or spatial capacity (**3**).

2.4.2. The vestibular system and hearing

Rapidly changing G-vectors might have physiological implications speaking for an even more *perfectly balanced vestibulo-visual system*.

New dimensions in testing of the hearing since a good *3D-audio discrimination* might be crucial.

2.4.3. Respiratory system

Additional respiratory stress might be the result by positive pressure breathing under high-sustained G (**4**). New selection-tests for inspiratory muscle capacity, tests to stage the effects eventual tobacco smoking has had on applicants.

2.4.4. Cardiovascular system

It is also an important task to more in detail establish what exact *factors constitute a good G-tolerance.* Cardiac function during G-stress and pain-provoking factors in high-sustained G might also influence selection.

2.4.5. Musculoskeletal system

A more balanced view on the *muscular strength* where not only explosiveness and fast-twitch muscle fibres are rewarded. After all when long sorties have to be performed the endurance parameters of the muscular and cardio-vascular system have to be screened and evaluated more.

Specific factors of the *back and neck* have to be considered in the selection (**5**). Among these factors we can predict bone-mineralization, range of motion in relation to strength factors. Condition of vertebral discs and spinal canal.

2.4.6. Cognitive and nervous system

The cognitive ability is truly a question of selection for the superagile pilot. Especially the challenging task to select those with both capacity to work within the "higher" cognitive domain but also extremely "present" in the situation at hand.

Stress resistance will be even more important than in earlier systems. Ways to measure the status and reactivity of the autonomic nervous system will therefore be important. Selection tests where flight stress can be simulated will be appreciated tools.

Try to establish a common opinion whether *intuition and creativity* are desirable traits in the superagile world. One could argue for such an opinion since fights including BVR, rapidly changing scenarios, uncertainties of threats etc. indicate the value of these traits.

3. TRAINING

Training has to be both *basic and specific* to give the best prerequisites for the pilot to handle the superagile situation.

3.1. HUMAN RESOURCES AND CONSTRAINTS

These are their contrasts. In *selection we focus on human resources* while in *training* we often try to overcome or *reduce effects of human constraints* and reach or move human limits, which might be possible to reach.

3.2. SUPERAGILITY TRAINING STRUCTURE

Training for this superagile environment has to be performed for different reasons. Firstly man will more clearly than ever be the restricting factor. Secondly flying time will be so expensive that ordinary training sorties will have to be complemented with a variety of other training regiments. Thirdly the rivalry between spatial orientation and tactical awareness will make it necessary to train both specified single tasks and also combined mission-like tasks.

Training could be divided in training to reduce the human constraints (physiological and mental training) and training which in some respect goes with the right PVI-format. This latter training will give familiarity with cockpit instruments and facilitate "pattern-recognition" when it comes to real flying. The training will aim at strengthening the human capability to withstand mental and physiological threat in a superagility environment.

The superagility training could also be seen as a "training structure" which has to be worked through (Figure 5.3.3-1).

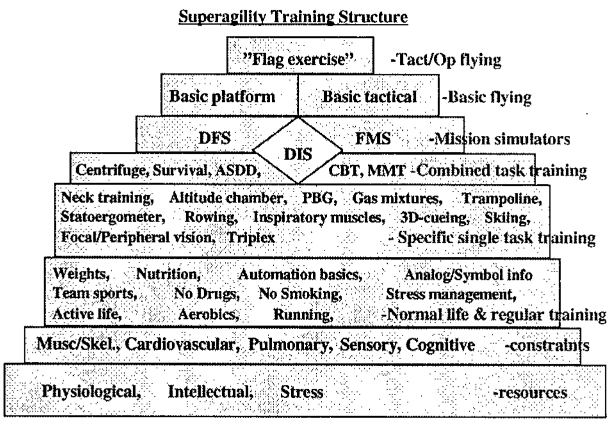

Fig 5.3.3-1 The Superagile Training Structure

In this superagility training structure we have earlier discussed the human resources who in this context are valid factors in the selection. In the following paragraphs of this section the human constraints and different parts of training are discussed.

3.3. HUMAN LIMITATIONS (INTERNAL CONSTRAINTS)

The human limitations in this scenario force us to focus on many training issues. Some of the factors, which could be considered to be human constraints in the superagile world, are mentioned below.

3.3.1. Cognitive function

The cognitive function of the pilot might not be a constraint in itself. But a lot of sensory information has to be processed in higher cognitive areas. And then we have an easy set-up for a conflict between the need not to lose the orientation in airspace and the need for effective use of higher cognitive functions according to the demands of the sortie. In addition physiological stress on the human system and perceived mental stress will reduce effectiveness. In conclusion one can state that there will be even more emphasis put on situational awareness (SA).

3.3.2. Sensory function

Signals to our 5 senses are crucial to orient ourselves in the agile world. Since flying is something so different from permanent residing on ground, which we are built for, man has to watchfully observe a lot of rather simple information. This information serves only the purpose of body orientation in the airspace

The *vestibular system* is sensible to different G-vectors, rotations, and translations. This system will be more stressed than ever before and it has to be adapted and if possible made less prone to react on unusual vestibular stimuli.

The *visual system* gives orientation cues but is also used for cognitive information. We need better and more intuitive information for spatial orientation, because the visual system is by far the most important sensory system and will also be the most important in flying. In years to come we will have a definite risk for overloading the visuals with "important" information on e.g. HMS/HMD: s, and VR-systems. The greater part of this information has to be percepted, interpreted, compared with elements in the long memory storage before any decisive action can be with taken. The conflict is given!

The *hearing system* gives orientation cues, informational load. An increasing importance is foreseen for the hearing system since e.g. 3D-audio cueing is to come thereby hopefully shortening the OODA-loop (observe, orient, decide, act) for this sensory system.

The *somatosensory system* is a simple sensory system in the context of flying. It gives some orientation cues and there are possibilities to artificially reinforce some of these cues.

3.3.3. Musculoskeletal function

High acceleration forces especially for back and neck, more if X-tra head worn equipment is used put a lot of stress to this system. In addition stress will

be caused by static postures due to harness restraints and certain demanding mission profiles like low-level flying (**5**). Superagile flying will demand from both gross-muscular strength and fine-motorics function. It will also stress the need for a superb ergonomic cockpit.

3.3.4.Cardiovascular function

Cardiovascular function is sensitive to acceleration forces, mainly head to foot (Gz). The heart itself is a pressure generator and integrated electromechanical device sensitive to acceleration as well as is the vascular bed of the central nervous system. Peripheral vascular beds seem also to be heavily affected by acceleration forces and thereby prone to pain reactions, e.g. arm pain (**6**).

3.3.5.Respiratory function

Respiratory function is sensitive to atmospheric pressure changes and different gas mixtures. Additional oxygen supply at times with overpressure will be needed to match the superagile envelop. To secure CNS function and facilitate inspiration pressure breathing during G (PBG) will be used. This will reveal the deficiencies in the human respiratory function.

3.4. NORMAL LIFE AND REGULAR TRAINING

As individuals in a modern high technological society we need to broaden ourselves in relation to egg the information technology revolution. Yet this increasing competence has to be matched with a physically active life to stay healthy. This may contain an inherited contradiction since many youngsters who are good at computers do not like physical activity too much.

3.4.1 Cognitive training

It will be important to have an increased knowledge of and possibility to *handle mental stress.* Since automation will become part of every man's day *understanding of automation-principles* will be important. One specific area of concern for most high-tech professionals and especially for the superagile pilot will be to find the right way to work with *symbolic information* at the same time *analog information* is presented to the person or pilot. The saying "Right information in the right format" will be more and more important. Presentation principles have to be looked carefully upon.

3.4.2. Life style aspects

Every pilot has to consider his personal eating-habits, sleeping-patterns, drugs and so on. And he must be physically active with the right balance between endurance and strength training.

3.4.3. Cardiovascular training

Pilot selection criteria like body-type, heart-cerebral distance, vagal and sympathetic nerve tone will be more important. It has been emphasized that it is not acceptable to perform extreme marathon training when flying high performance fighters (**7**). Yet it must be pointed out that distances up to 5-7 miles x 2-3 per week will be of no harm if the training contains high intensity peaks.
A well-conditioned cardiovascular system has a great importance when considering multiple sorties and limited possibilities for rest as in a war situation. A variety of different sports can be performed to achieve needed goals.

3.4.4. Musculoskeletal training

In recent years it has been a focus on strength training. A sufficient muscular capacity will still be an important factor in superagile flying but one has also to focus on the supporting tissues like back and neck with its bony structures, ligaments and discs. The way of modern living including working conditions where one often sits in front of a desk or a laptop is fundamentally wrong considering the heavy work, static or dynamic, which a high performance pilot sometimes has to exert.
A young pilot of tomorrow might as well have a suboptimal bone mineralization (**8**). To adapt to physical requirements he or she will have to train the musculoskeletal system over months or even years to correct deficiencies.
Superagile fighters might also add systems for the pilot that will increase the load on the neck/back. Device integrated to the helmet will stress these structures. Already today there is evidence that the aging process of the neck of high performance pilots is accelerated compared to age matched controls (**9**). The clinical significance of this is unclear.

3.5. SPECIFIC SINGLE TASK TRAINING

This type of training will strengthen some specific abilities the pilot have to show in the superagile cockpit. Still this training will be performed outside the cockpit.

3.5.1. Cardiovascular and muscular training

To withstand high acceleration forces (normally Gz) is a primary goal. This will also include the area of negative Gz or the "push-pull" phenomenon (**10**). Factors important are actual G-experience, conditioned cardiovascular reflexes including both central adaptive mechanisms and local training effects on certain vascular areas such as the arms, to prevent arm pain. There are known device, which can be used for improvement in these areas like the statoergometer of Russian origin, rowing machines, downhill skiing.

3.5.2. Sensory training

Of the 5 senses the human have for information, the visual system is by far the most important in flying. To be able to move in 3 dimensions unlike the situation on ground, the pilot in his AC has to overcome a lot of erroneous signals given from e.g. the vestibular and the somato-motor systems. A great deal of work has therefore to be focused on training for the visual apparatus. Orientation information simultaneously presented with a high flow of tactical information will or rather must be given in two different formats so the pilot can work in parallel with the information. This is very important since information overload of the pilot is an immediate threat in superagile flying.
The vestibular system has to be adapted to a variety of new movements in flying like yaw, side slipping, translations and unusual velocity-vector movements compared to regular flying.
In addition to the visual system there are now efforts to also include the hearing system into the informational inflow. Then we must have in mind that pilots in earlier stressed situations (e.g. Vietnam war) have had the tendency to shut off information they have considered to be annoying and distracting rather than helping.
With 3-D hearing information there will be a possibility to keep track of much more auditory information compared of today's situation. Yet the risk for informational overload of the pilot will always be critical.
The sensory training can contain formal sensory training outside the cockpit like the Triplex and Trampoline used in e.g. Germany and Sweden. Training of the spatial ability like 3D-cueing and exercise training focal and peripheral vision might be of specific value.

3.5.3.Respiratory training

Training has to include hypobaric exposition with possibilities to experience hypoxia and preferably also rapid decompression training.
With high performance AC in the inventory it has been shown that positive pressure breathing during G (PBG) gives a definitive advantage. Intrathoracal over pressurization of up to 70 mmHg has been tested. The overall consensus today seem to be around 50-60 mmHg at 9G(**11**). The ideal pressure schedule in relation to G is still under debate. The advantage of PBG seems to be an increase in G-endurance. One important factor for this might be the decreased load with PBG for the inspiratory muscles. These muscles are weak considering the normal physiology at 1 G. In this situation the lungs are almost passively filled with air as a function of the flattening diaphragm following the abdominal volume displacement acting in the same direction as the Gz-vector.
In the high-G situation there is an urgent need for the auxiliary respiratory muscles above the lungs to try to counteract the Gz-vector in the inspiratory phase and "lift" the lungs to get air. Activated G-suit will tend to counteract the filling process of the lungs by abdominal upward displacement during G. PBG seems to give a substantial help in this respect. Device needed for the respiratory system will be altitude chamber, PBG-systems where especially the inspiratory phase of the cycle can be trained.

3.6. COMBINED TASK TRAINING

The type of training is much more functional and has a clear aim to be more directly useful for flying. This will also mean that there will be specific devices developed to be means to prepare the pilot for e.g. the cognitive work or to be able to withstand specific physiological stresses.

3.6.1. Cognitive training

Computer Based Training (CBT) and Multi Mission Trainers (MMT) are needed tools to give fundamentals of AC systems and of the superagile arena. Cockpit outlay, display arrangement and content as well as familiarization with buttons and switches make a good start for actual flying. Instructors can guide and interact with the trainee.
A broad knowledge of the AC, systems, weapons and the tactical and operational facts of the situation are crucial.
One of the biggest problems is the informational load on the pilot. Therefore information systems, which are more "intuitive", have to be developed. With increasing information to the pilot, decision support systems will come. Many of these systems will be automated to some extent. Still there will always be a need for the pilot to know the "actual state" of the automated process.

3.6.2. Sensory training

The visual and vestibular systems can be regarded as the most stressed sensory systems in the superagile world. Both adaptation to unusual stimuli and also suppression of unwanted side effects will be crucial.

Both simple gyro-simulators and advanced disorientation trainers are useful tools.

3.6.3. Cardiovascular and muscular training

High-sustained G and G-peaks of 9 or more are inevitable effects of the superagile world. The absolute need for an adapted cardiovascular system and muscular strength to be able to fight in this arena is already known with today's AC systems. High-speed BVR-scenarios stress this even more. The human centrifuge with sufficient G-onset rate is a basic tool for this. Different types of centrifuges from free-swinging single-gimballed centrifuges to modern dynamic flight simulators with both roll- and pitch-control will be used. With the more modern devices even push-pull training can be performed.

3.6.4. Survival

Pilots must also be prepared to leave their AC in case of a malfunction or an unwanted outcome of an engagement. Summer- and winter-survival training are ultimate combined training regimes where most everything from the Superagility Training structure can be applied.

3.7. SIMULATION

Integrated training, where most factors that have an implication in flight are used, is an intriguing task. And this is when *Simulation* comes into play. There is a justified need for *realism* and complexity in this form of training. The more realistic the simulation is the more will it bring forward actual stressors from real flying. In simulation both cognitive and physiological stressors are used.

In addition simulation can also be focused on decision-making and performance under all kinds of stress.

Coming to this part of the training, more complex device almost up to real flying have to be used. The best possible right format will then be given to produce all different factors including stress.

Due to the ever-increasing costs of flying-time simulators, though they often are very expensive, have to be used. And knowledge and experience might have to emanate more from simulator-experience in the superagility environment even though it is of outmost importance to fly.

Therefore also distributive interactive simulation (DIS) will be used more, where ACs "powered" and data-linked with each other and different simulator systems in a network will "play" together.

4.1. FLIGHT SIMULATION

Since the visual system by far is the most important in flying, much emphasis has been put on making visual realism in flight simulation. But in the superagile arena there is also a need for expressing the information loads and the physiological stress.

4.1.1. Visual simulation

The best visual simulators are domes or full-mission- simulators (FMS). They are static but they provide almost unlimited field-of-view (FOV). Domes usually are very big 20-40 ft in diameter and the image can be projected at an infinite distance. With head- and eye- trackers it is also possible to have an area of interest where the image-resolution is very good. The drawback can be motion sickness in inexperienced and individuals prone to this "visual overflow" of information (**12**).

The visual systems can be used in combination with so called "G-seats" where the tactile as well as the proprioceptive systems can be stimulated by e.g. shaker system, retractable harness and inflatable seat-cushion (**13**).

4.1.2. Motion based system

Though many civilian airlines have a need for a 6 degree-of-freedom (6DOF) device there is not so much need for that in the military applications. G-forces are not possible to create to a necessary degree. In addition most military simulators where motion bases were linked to each other have been disconnected since there were a lot of problems with visual and other sensory mismatching, causing a frequent tendency to motion-sickness.

4.1.3. Dynamic flight simulators

These gimballed centrifuges are a clear development from the centrifuges with a free-swinging gondola. Most of them have controllable pitch- and roll- axis. (The Dynamic Environmental Simulator at Wright-Pat AFB has also yaw-capacity, but only 1G/sec onset rate). Together with a G-onset capability of 6-10 G/sec the devices should be capable to give the superagile pilot most of the experienced G-vectors in a superagile AC. In addition there is hope that a very good visual system and a closed-loop control system could give the dynamic flight simulators "flying characteristics".

Yet there are some precautions to that. For vestibulary reasons the pilot could not move his head too much since he then will have heavy vertigo due to coriolis-effects. To minimize these problems most dynamic flight simulators have an arm-length of 25 ft or more.

Existing or oncoming facilities are situated in: US, Singapore, Germany, France, Japan, Sweden and UK (**14**).

4.1.4. The Combined Acceleration Flight Simulator (CAFS)

This is a concept from the early ´90s (USAF Armstrong Lab (**15**)). The concept involved a multi-gimballed cab suspended by electromagnets in a large circular loop with a radius of over 200 ft. Together with a wide-FOV visual system and man-in-the-loop control this simulator would have minimized Coriolis´ effects and given an outstanding possibility to simulate almost everything in the superagility arena.

5. PILOT-VEHICLE-INTERFACE (PVI)

The pilot vehicle interface (PVI) must in the future be a lot more adapted to man. That means the PVI have to be built according to a human centered design protocol. Some of these factors should be:

- Ergonomic cockpit
- Simple platform to fly (carefree manoeuvring)
- Clear distinction between displays for orientation purpose and displays for tactical awareness.
- The right information in the right format at the right time (no information-overload).
- Logic decision support.
- Pilot-monitoring system with situation feedback on the information-, decision- and control systems.
- The "right" degree of automation.
- Very good escape system and protective equipment.

The PVI has also to be placed as operational as possible in advanced simulators like FMS and DFS. These two very "much-alike" AC simulators should also ideally give a lot more physiological and mental stress compared to the more cognitive trainers like CBT and MMT.

SUMMARY

In this chapter a "superagility training structure" have been discussed and proposed for (Figure 5.3.3-1). The super agile pilot will in the new superagility arena be clearly dependent on both old training principles but also on training where some new interacting factors might come into play:

- At first *Selection* plays a major role with physiological, intellectual and stress management resources.
- Certain *human constraints* like musculoskeletal, cardiovascular, respiratory, sensory and mental are discussed.
- *Normal life and regular training* where almost everything the pilot does also have a definite implication also on flying.
- *Specific single task training* where a pilot trains crucial abilities like G-tolerance, back/neck-tolerance and so on. Today there is a lack in this area of specific training. There is also a need for training devices for pilots regarding the sensory system and the cognitive performance.
- *Specific combined tasks training* where the pilot have to train in a more complex way, e.g. survival training or mission scenarios in a Multi Mission Trainer (MMT).
- *Full ground mission task* where the pilot uses a Full Mission Simulator (FMS) or a Dynamic Flight Simulator (DFS).

Some parts of the Superagility Training Structure have not been a scope in this chapter. They are briefly mentioned below.
Basic flying consists in this context of platform training and tactical training and are the formal parts of flying. Due to the ever-increasing costs of flying, the real portion of a pilot's life in the air most probably will decrease. A different solution would be to get "cheap time" in the air e.g. with a modern propeller-AC.
Tactical/operational flying where "flag-like" exercises are as close to a real war-scenario pilots in general wish to come. As stated above actual flying will be even more expensive and therefore we most probably have to try to find measures to give more and more realistic training concepts. And when it comes to real flying it could not always be done at first with instructor pilots (IPs). This together with increasing complexity of all systems might in a superagile AC stress the need for air collision avoidance systems (ACAS), ground collision avoidance systems (GCAS), auto recovery or other "fix-it"-procedures.

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